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ELECTRICAL ENERGY CONSERVATION PROGRAMS THROUGH ENERGY EFFICIENCY LABELLING FOR HOUSEHOLD REFRIGERATORS AND FREEZER IN BRAZIL, GERMANY AND THE UNITED STATES

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PROGRAMAS DE CONSERVAÇÃO DE ENERGIA ELÉTRICA ATRAVÉS DOS PROGRAMAS DE ETIQUETAGEM PARA GELADEIRAS E CONGELADORES DOMÉSTICOS NA ALEMANHA, NO BRASIL E NOS ESTADOS UNIDOS

RESUMO

Nos últimos 30 anos vários países desenvolvidos têm trabalhado em programas que visam um consumo mais racional para a eletricidade. Por meio de certificações de eficiência energética a indústria mostra aos seus consumidores sua capacidade de oferecer conforto com o menor consumo de energia. Algumas etiquetas já são largamente conhecidas e influenciam o poder de decisão do consumidor no momento de compra de novos eletrodomésticos. Neste contexto, o presente trabalho objetivou identificar, comparar e analisar programas de rotulagem de eficiência energética em refrigeradores e congeladores elétricos. Para tanto, foram consideradas as metodologias para rotulagem na Alemanha, no Brasil e nos Estados Unidos. A investigação de caráter qualitativo e quantitativo foi realizada por meio de revisão bibliográfica e documental e análise comparativa das metodologias dos três países. Entre os principais resultados verificou-se que as metodologias têm algumas semelhanças, entretanto, a variável temperatura externa de acordo com a região geográfica tem influência sobre os cálculos na Europa, mas não é considerado no Brasil.

Palavras-chave: Eletrodomésticos. Etiqueta de eficiência energética. Programas de conservação de energia.

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ABSTRACT

In the last 30 years several developed contrives have been working on programs aiming at a more rational consumption of electricity. Through energy efficiency certifications the industry shows its consumers their ability to offer comfort with the lowest energy consumption. Some labels are already widely known and influence consumer decision-making when buying new appliances. In this context, the present work aimed at identifying, comparing and analyzing energy efficiency labelling programs in electric refrigerators and freezer. Within this context, methodologies for labelling were considered in Brazil, Germany and the United States. Qualitative and quantitative research was carried out through a bibliographical and documentary review and a comparative analysis of the methodologies of the three countries. Among the main results it was verified that the methodologies have some similarities. Nevertheless, the outdoor temperature variable according to the geographical region influences the calculations in Europe, but it is not considered in Brazil.

Keywords: Household Appliances. Energy Efficiency Labelling. Electrical Energy Conservation Programs.

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1 INTRODUCTION

Improving energy efficiency is key to successful energy transition (NAPE, 2014). Combining the recently implemented efficiency programs among 18 major economies in the world, its estimated the reduction over half a gigaton of CO2 by 2030 (CLASP, 2018). The International Energy Agency – IEA states that energy efficiency measures can reduce up to 10-15% of global CO2 per year at no additional cost.

Society in all levels needs to work for achieving the efficiency objectives, developing technologies, and investing capital in the energy efficiency transition. However, the commitment of the public is an essential factor on energy transition by driving the energy consumption, whether as politicians, businesspeople or private individuals. The success of the energy transition is decided as much by a combination of technology and people (DENA, 2018).

As a matter of fact, the energy efficiency transition is an extremely important action that shapes entire countries by elaborating policies and changing their customer's behavior. To illustrate, Brazil set a document called "*Plano Nacional de Energia 2030*" (National Energy Plan 2030 – PNE 2030), which presents a series of studies related to energy efficiency. Some fronts of the PNE 2030 focus on characterization of electrical energy usage, determining the potential of energy savings by electrical energy usage and perspectives of electrical energy conservation. In order to elaborate this document, cooperation between many organizations made necessary. These efforts resulted on a plan that aimed to show to the general public a way of how to collaborate for the energy transition in Brazil.

Labelling programs initiated back in the 1940s in the United States, characterized by compulsory programs, defined by law. Its objectives were to warn about side effects in a group of products concerning the environment or even the product user (Guerón 2003). In the 1970s, decade known for many political and environmental occurrences, for the constructions of nuclear power plants and the petroleum crises many environmentalists began a movement enforcing the necessity of the environmental friendly seals (Neuenfeld 2006). After this period, many programs changed its character to a voluntary labelling programs, concerning mainly food products, providing science-based dietary guidance. However, they were still distrusted by the public (Kohlrausch 2003).

As an example and case of study, Germany was one of the pioneers on energy efficiency strategies for the European Union, tackling energy usage differently from the other countries. Many countries based their policies over the hypothesis that the economic growth was

associated with great energy consumption because it was assumed that the more energy a country inputs the more economic growth it would have. For that been said, most of these programs and similar actions were a reflection of the 1973 oil embargo that escalated the energy price. To illustrate, spends from West Germany's energy consumption had to allocate $8 billion more than the previous year as a result of an increase in oil price by the Organization of the Petroleum Exporting Countries - OPEC (ALLIANCE, 2013).

By the year of 1973 in Brazil, the National Institute of Metrology, Quality and Technology - INMETRO, was created by law to support Brazilian enterprises to increase their productivity and the quality of goods and services. The institute is focused on improving the quality of life of ordinary citizens by increasing competitiveness of the economy through metrology and quality (INMETRO, 2018). Years later, in 1985, INMETRO working with "Ministério da Indústria, Comércio Exterior e Serviços - MDIC" (The Ministry of Industry, Foreign Trade and Services), started a program called "Programa Nacional de Conservação de Energia Elétrica - PROCEL (National Program for Electrical Energy Conservation)", targeting electricity conservation in household appliances. In addition, the program was focused on reducing energy consumption on appliances such as refrigerators, freezers and domestic air conditioners.

The European Union - EU, Energy Labelling Program officially started on September 22nd 1992, by the Council Directive 92/75/EEC, starting with the product labelling information for large household appliances such as refrigerators, freezer, washing machines, driers, dishwashers, ovens, water heaters, hot-water storage appliances, lighting sources, and air-conditioning appliances. The regulation has undergone changes and updates to better fit the current situation been reformulated in 2010, accompanied by supplementing Regulations for specific appliances. Besides, Germany also adopted, and is working on to accomplish a very ambitious 50% energy reduction for 2050 for its Economic Wide Targets, based on the year of 2008 (ALLIANCE, 2013).

The United States, first movements towards energy efficiency dates back to 1975, when the Congress did pass the Energy Policy and Conservation Act, which sets minimum standards of energy efficiency for many major appliances. Although, the story behind ENERGY STAR® has its roots related to the EPA – Environmental Protection Agency's Atmospheric Pollution Prevention Division. A dedicated group of staff had been working for a number of years to find cost-effective ways to reduce greenhouse gas emission by analyzing data. Afterwards, many businesses and industries have been visited, trying to develop strategies on energy efficiency. Around 1992, what they found out was that the energy demand of computers stood out,

confirming the magnitude of potential energy savings and setting the stage for the very first ENERGY STAR® qualified products. Starting with the label for office products, labelling computers and displays. Where ENERGY STAR® stands to bring credible, objective information to businesses and consumers so they can save money and reduce the greenhouse gasses emission by using more efficient appliances. It did not take long for the United States to expand to other appliances. In the mid-90s, the United States Department of Energy – DOE, together with EPA included in the program household products such as dishwashers, refrigerators, heating and cooling equipment and lighting. Similar to the programs that Brazil runs, the United States has the EnergyGuide, a compulsory labelling program for major appliances, and ENERGY STAR® as a voluntary Energy Efficiency Award Seal (Energy Star, 2012).

The dilemma of providing customers with appliances to fulfill their needs rises the energy usage overall at the same point the industry is striving to achieve higher efficient index to fight climate change, resulting on a race, where countries compete to rank their names higher on the leaderboard of well-developed sustainable economies. Cooperation between countries on sharing their policies overseas is influential on breaking the energy barriers. After many years, countless approaches and innumerous partnerships with industries, how to progress with this energy efficiency barrier? Assuming that technologies to help on calculation are attainable, means of manufacturing are well-dominated by men allied with machinery and studies that leads us to affirm that earth resources must be harvested wisely in a way to diminish our negative impacts on the industrialization processes, the next move might be hidden on changing the mindset of the population, by virtue of for them and because of them that all it exists (Energy Star, 2012; Alliance, 2013).

Within this context, the objective of this bachelor final project was to identify, to compare and to analyze programs associated to the energy efficiency labelling for household refrigeration appliances. It was considered the three previously mentioned countries: Brazil, Germany and the United States. The topics focused on regulations referring energy labelling programs for refrigerators and freezer.

Firstly, it was presented a bibliographic and documental review concerning the subject of study examined and detailed. Secondly, it was explained in Methodology section how the investigation was carried out. The findings and discussion surrounding the thematic were presented in Results and Discussion section. Finally, it was presented the conclusion accompanied with suggestions for future researches.

2 LITERATURE REVIEW

In this section, the bibliographical and documental review was presented, covering the regulations and recent studies regarding to energy conservation programs. In particular, each country's regulation about the labelling program for refrigerators and freezer was searched and detailed. The most significant topics for the theme are described on the following sub-sections.

2.1 Brazilian Efficiency Labelling Regulation

As mentioned in the introduction section, INMETRO focus on improving the quality of life through metrology and quality. Correspondingly, the objective of its regulation is to coordinate business relations between INMETRO and the suppliers that are prone to stamp their products with the "Etiqueta Nacional de Conservação e Energia – ENCE" (National Energy Conservation Label). In fact, refrigerators and freezer in Brazil were the first objects of importance to saddle an agreement between the regulatory body and the suppliers.

The program aims to supply customers with important information with respect to the appliances they intend on buying. In 1993, was created the "Selo PROCEL de Economia de Energia" (PROCEL Energy Economy Seal). This endorsement program, complementary to the PBE, stamps annually the best ranked products in each category promoting the same goals as the ENCE. The program encourages competitiveness inside the industry, by continuous improvement process and supporting education to increase customers' choosing abilities. For instance, PROCEL Energy Economy Seal is already present in 41 categories of products labelled by ENCE. The labelling started with refrigerators and freezer in 1995 up to the most recent, Public LED lighting, in 2017.

The document analyzed for this labelling specific regulation was introduced and was set to be on force from January first 2003 (INMETRO, 2003). Since then, INMETRO is responsible for all the updates and reviews. Thus, this was the last version obtained in their website. However, after a more in depth examination in MDIC's database, a ministerial order was found. Called "*Portaria* nº577 de 18 de novembro de 2015" (Jornada, 2015). This ordinance updates the specific regulation prior this date and will integrate this bachelor final project's literature review.

With respect to the steps that are covered in the Brazilian Efficiency Labelling Regulation, many topics are covered in the 2015 version when compared to 2003 version,

starting from how to get the ENCE on the product, up to how the product can be banned to use the label because of conduct.

2.1.1 Process to obtain the ENCE

Regarding the phases on how to obtain the ENCE, in the Specific Regulation for Refrigerators and Freezer. They are organized in 6 steps represented in the following sub-sections (INMETRO, 2003).

2.1.1.1 Labelling request

In this phase, the suppliers that wants to commit to the labelling program must submit a form that is attached in the Specific Regulation for Refrigerators and Freezer along with the datasheet of the product. The submission of a specific form is mandatory for each different product desired to obtain the certificate.

In the scenario that the supplier is absent of its own laboratory to conduct the tests, after receiving INMETRO's approval, must apply for an accredited laboratory.

2.1.1.2 Labelling request analysis

INMETRO is responsible to analyze and notify the supplier about the result. In the scenario of been approved, a date for the data collection and for testing the product will be scheduled.

All the documents that were submitted to the labelling program request process must have its trustworthiness validated by the original document.

2.1.1.3 Production Line Documentation

Thirdly, the supplier must submit for approval, to the accredited laboratory, information about the product model that is going to be tested.

The information required are: at least 2 (two) drawings defining internal volume of each compartment, for both refrigerated and frozen; descriptive memorial evidencing the calculations of declared volumes; thermal load plans to be simulated and certified; orientated

documentation about how to operate the appliance settings; and finally, the updated user's manual.

2.1.1.4 Interlaboratory verification phase

This subsection represents the certification of the supplier's laboratory technical capacity. The supplier is able to submit to an accredited laboratory, one or more products, previously tested along with testing reports. The products must carry a previous categorizing testing and energy consumption results to be checked by the laboratory.

The accredited laboratory, after confirming the products and documentation submitted by the supplier, schedule a date for testing and validation. The supplier's laboratory is considered accredited to proceed with testing in case the results from the validation do not exceed 5% (five percent).

2.1.1.5 Approval phase

INMETRO has the responsibility, after notified by the accredited laboratory, to acknowledge the product labelling class in the supplier's "Relação de Produtos Aprovados" – RPA (Approved Products List), and also include the product in the Efficient Tables released 7 days after from received the results. The disclosure needs to be updated periodically, with a maximum period of 6 (six) months between Tables update.

2.1.1.6 Production Monitoring Phase

The procedure of monitoring happens after 180 (hundred and eighty) days from the contract formed and at most twice a year. This procedure demands selecting 1 model of each voltage, for testing in the accredited laboratory.

In addition, it will be accepted only product selection from the production line, avoiding any manipulation. After been notified, the supplier has a 48 (forty-eight) hours deadline to submit the models to the laboratory, starting from the notification date.

The testing character applied follows temperature classification and energy consumption tests. However, when notified, the tests can cover also temperature holding and freezing capacity tests.

For instance, the result from the selected models must agree with the Specific Regulation, meeting the limit value of each criterion, as follows:

- The temperature informed by the supplier must coincide with the value tested
- Energy consumption informed by the supplier may not exceed 7.5 % (seven and a half percent) of the specified in the Specific Regulation
- Temperature holding time informed by the supplier may not exceed 15% (fifteen percent) of the specified in the Specific Regulation
- Freezing capacity informed by the supplier may not exceed 15% (fifteen percent) of the specified in the Specific Regulation

With respect to inadequacy during any of the tests, whereas the results do not respect the values presented above, this labelling specific regulation indicates measures as a result of each type of inadequacy.

Firstly, verified variations or nonconformities in the energy consumption tests demands that 2 (two) other units of the same model and voltage must be sent for testing. Then, it is calculated a mean value of the three units. The mean value calculated may not pass 5% (five percent) from the supplier's informed value.

Secondly, verified variations or nonconformities in the temperature holding time tests demands that 2 (two) other units of the same model and voltage must be sent for testing. Then, it is calculated a mean value of the three units. The mean value calculated may not pass 10% (ten percent) from the supplier's informed value.

Thirdly, verified variations or nonconformities in the freezing capacity tests demands that 2 (two) other units of the same model and voltage must be sent for testing. Then, it is calculated a mean value of the three units. The mean value calculated may not pass 10% (ten percent) from the supplier's informed value.

Finally, in the scenario where the three units do not fulfill the requirements of this labelling specific regulation, the product sent for testing is subjected to:

- Classification nonconformity: suspension of using the ENCE
- Energy consumption nonconformity: Label information updated using the mean value obtained
- Temperature holding time and freezing capacity nonconformity: Labelling revision or provisory suspension of using ENCE

2.1.2 ENCE Applicable Norms

With regards to the norms and standards applicable for categorizing and calculating the efficiency in this labelling specific regulation, this regulation is based on the standards in the list as follows.

Table 1 – Referenced International Standards

ISO 5155	Household refrigerating appliances - Frozen food storage cabinets and food freezers - Characteristics and tests methods
ISO 7371	Household refrigerating appliances - Refrigerators with or without low-temperature compartment - Characteristics and tests methods
ISO 8187	Household refrigerating appliances - Refrigerator-freezers - Characteristics and tests methods
ISO 8561	Household refrigerating appliances - Refrigerators, refrigerators-freezers, frozen food storage cabinets and food freezers cooled by internal forced air circulation - Characteristics and tests methods
IEC 62.552:2007 + Ed. 1.0	Household refrigerating appliances - Characteristics and test methods

Source: Adapted from Jornada (2015)

2.2 Germany Efficiency Labelling Regulation

The document that establishes the conducts to be followed in Germany was developed by the European Parliament working with European Council. The same documents rules for all the Member States, working in cooperation to meet Union's 2030 energy-efficiency targets (ALLIANCE, 2013).

This Regulation aims to allow customers to choose more efficient products by supplying relevant information. The first approach for this regulation began with Council Directive 92/75/EEC of 22 September 1992, which was reformulated by Directive 2010/30/EU of the European Parliament and of the Council of 19 may 2010.

Looking after the topic of refrigerators and freezer, the European Union released Commission Delegated Regulation (EU) No 1060/2010 of 28 September 2010, supplementing Directive 2010/30/EU, setting the methodology for household refrigerating appliances.

In addition, Commission reviewed the effectiveness of Directive 2010/30/EU. It was identified the need to update the energy labelling framework to improve its effectiveness. Replacing Directive 2010/30/EU by Regulation (EU) 2017/1369, the scope was maintained.

This document of 2010 will serve as base for this bachelor final project by virtue of the Regulation No 1060/2010 talks specifically about household refrigerating appliances while the

recent amended Regulation of 2017 replaces the overall scaling gradually along with some minor changes.

In other words, Regulation of 2017 aims to promote a homogeneous A to G scale. With a deadline on 2 August 2023, Delegated Acts aims to introduce A to G rescaled labels. The new rescaling target product groups pursuant to Directive 2010/30/EU. The new approach will affect displaying the rescaled label both in shops and online. The changes must happen 18 months after the date of entry into force of the delegated acts adopted pursuant to Regulation of 2017 that was of August 1st 2017, and complementing by the obligations of the suppliers in relation to the product database shall apply from January 1st 2019.

The Directive of 2010 also describes the responsibility of the Commission, of reviewing this labeling regulation, as new technological processes arise. The period of reviewing is also described as a period of no longer than 4 (four) years after the Regulation entry in force. Particularly assessing the tolerance set, and the possibility of removing or reducing the values of the correction factors set.

2.2.1 Requirements for the European Labelling

The Regulation sets requirements for electric mains-operated household refrigeration appliances from 10 (ten) to 1500 (thousand and five hundred) liters, including those sold for non-household and battery-powered. It is not covered in the European Regulation: refrigerating appliances powered by energy sources such as liquefied petroleum gas (LPG), kerosene, and bio-diesel fuels; battery-powered refrigerating appliances that can be connected to the mains through an AC/DC converter; custom-made refrigerating appliances; refrigerating appliances for the tertiary sector application where the removal of foodstuff is electronically made and chilled drinks dispensers.

Additionally, the European Regulation demands tests beyond the energy factors. More specifically, it is a value of testing, the airborne acoustical noise emissions.

For the purpose of checking conformity requirements, Authorities should test 1 (one) household appliance. In case the measurements do not meet the declared values by the supplier within the range defined in the Regulation, the measurements shall be made on 3 (three) more of the same products. The mean value of these three products shall meet the requirements within the same Regulation.

2.3 United States Efficiency Labelling Regulation

As mentioned previously, EnergyGuide is a mandatory program on all major appliances, organized by the Federal Trade Commission – FTC. It is represented by the law "Title 10 CFR Part 430 – Energy Conservation Program for Consumer Products" using Subpart B and C that consequently integrated this bachelor final project documental basis, considering the latest document with effective date on 17 January 2017.

Another document researched was the "Title 16 CFR Part 305 – Energy and Water Use Labelling for Consumer Products Under the Energy Policy and Conservation Act (Energy Labelling Rule)". This document sets calculations and orientations guidance for the use of the energy label on appliances.

The Energy Policy and Conservation Act – EPCA prescribes energy conservation standards for commercial and industrial equipment. In addition, the program requires from the DOE to determine if more stringent amended standards for these products are technologically feasible and economically justified, and would save a significant amount of energy (CFR, 2017).

Under the Act, DOE's energy conservation program for covered products consists essentially of four parts:

- Testing;
- Labelling;
- The stablishment of Federal energy conservation standards;
- Certification and enforcement procedures.

The Federal Trade Commission (FTC) is generally responsible for labelling issues for consumer products, and DOE implements the remainder of the program.

3 METHODOLOGY

In this study a bibliographical and documental research was done in order to obtain the information to identify the energy efficiency program. It includes both qualitative and quantitative character. Firstly, in the Results and Discussion section, it was presented the relevant information about each country's labelling program. Secondly, a simple table with

side-by-side comparison between some characteristics of each program. Thirdly, a simulation between the European and Brazilian programs with its respective labels in contrast. To sum up, a brief discussion about both the methodologies was presented.

3.1 Qualitative Study

In the qualitative character, a research through each countries responsible regulation body for the energy labelling and standards website took place. The documents analyzed were the INMETRO's Specific Regulation of 2003, and the Ministerial Orders of 2006 and 2015 for Brazil. The composition of these three sources made necessary because of missing information. For Germany, the latest information analyzed is the Commission Delegated Regulation emitted from the European Parliament in 2011. For the United States, information was obtained from the legislation present in the Code of Federal Regulation of 2007 and 2011, related with the Department of Energy. In the following sub-section, each country's labelling program information is presented.

3.2 Quantitative Study

In the quantitative character, it will cover a description between the programs implemented in Brazil and in Germany. The EnergyGuide program is not comparable with the methodology used in this bachelor final project. This decision was led by the fact that the EnergyGuide program is a monetary range classification, not covering a scale of letters, usually on a range from "A to G". The programs between Brazil and Europe are similar in its visual frame, differing by the calculations.

Additionally, a comparison between methodologies occurred putting side-by-side the calculation methodology and visually each label, through simulating the framework of each label, for better understanding. The results from this methodology is presented in the section 4 – Results and Discussion.

4 RESULTS AND DISCUSSION

This section presents the results of the methodology followed by the analyzes made between the three countries. It is emphasized in this section the peculiarities discussed. The

intention of this discussion is to bring to light best practices concerning the theme. After the analyzes of the three methodologies, it was possible to identify some similarities on them.

4.1 Information About the Labelling Program

The relevant information identified in each country's regulation is presented by country in the following sub-sections.

4.1.1 Brazil

As mentioned before, PBE is organized by a group of governmental and private sectors. However, INMETRO is the responsible regulatory body for the program. In the search in the INMETRO's online database, looking for documents related to labelling household refrigeration appliances, the available document was "Regulamento Específico Para Uso da Etiqueta Nacional de Conservação de Energia – ENCE, Linha De Refrigeradores E Seus Assemelhados" (Specific Regulation for the Use of the National Energy Conservation Label – ENCE, Line of Refrigerators and Similar Appliances).

The document dates back to 2003, representing the fifth edition of a document with no revisions containing 37 (thirty-seven) pages. As mentioned in the Literature section, that is not the latest regulation.

On the other hand, the newer specific regulation, after the ministerial order of 2015, replaces the older version. This document brings general information about its objective, characterization, safety methodologies, how to use the ENCE, process phases on how to obtain the ENCE and appendix with methodologies for categorization. The most recent documents missed some of the important information about the classification that was contained in earlier regulations, leading to difficulty to analyze one single document, so the regulations had to be put side-by-side like a puzzle.

4.1.1.1 Brazilian Product Classification Classes

The methodology applied to classify in Brazil aims to separate the products in comparable groups. The classification takes as reference the group of international standards mentioned in the Literature Section and in the physical characteristics of the product. As a note: Voltage, supplier or size are not characteristics for creating new groups.

The most recent classification is defined on Table 2, described in the Regulation of 2003.

Table 2 – Brazilian Refrigerator Classes

Class	Designation
1	Refrigerator / mini-bars
2	Refrigerator with defrost
3	Refrigerator-freezer
4	Refrigerator-freezer with defrost / side by side / French door
5	Chest freezer
6	Upright freezer
7	Upright freezer with defrost

Source: Adapted from Jornada (2015)

4.1.1.2 Brazilian Calculation Methodology

The calculation in the ENCE program demands straightforward calculation after having access to the input's value. Using the input values from Table 6 and the formulas below. The results will be exposed and discussed in the next section.

There are 3 (three) formulas to calculate the Energy Efficiency Index for Brazil. As follows: Adjusted Volume (Equation 1), Average Energy Consumption (Equation 2) and Energy Efficiency Index (Equation 3).

$$AV = Vr + f.Vc \quad (1)$$

$$Cp = a.AV + b \quad (2)$$

$$Ie = C/Cp \quad (3)$$

where:

$AV = Adjusted\ Volume$

$Vr = Refrigerant\ Volume$

$Vc = Freezer\ Volume$

$f = Star\ factor$

$C = Monthly\ Energy\ Consumption$

$Cp = Average\ Monthly\ Consumption\ (for\ a\ base\ model)$

$a\ and\ b\ are\ adjustment\ factors\ for\ each\ model\ class$

$Ie = Energy\ Efficiency\ Index$

4.1.2 Germany

The regulation applied in Germany is the same as the regulation for the Member States of the European Union. The regulation is a cooperation between many organizations, represented by the European Parliament and the Council. In a search for the European Union Law, the accessible documents online were: Directive 94/2/EC, Directive 2010/30/EU, Regulation (EU) No 1060/2010 and Regulation (EU) 2017/1369.

As described earlier, the chosen document, for a matter of accordance to the subject of this study, was the Regulation (EU) No 1060/2010, analogous to household refrigeration appliances. The analyzed 2010 regulation contains 30 (thirty) pages.

This Regulation discuss about: The subject of matter and scope, Definitions, Responsibilities of the involved parts, Measurement methods, Verification procedure with more complementary information.

4.1.2.1 German Product Classification Classes

Following, the classification in Europe, each category is defined by the specific compartment composition and it is independent of the number of doors or drawers.

The most recent classification is defined on Table 3, described in the Regulation of 2010.

Table 3 – European Refrigerator Classes

Class	Designation
1	Refrigerator with one or more fresh-food storage compartments
2	Refrigerator-cellar, Cellar and Wine storage appliances
3	Refrigerator-chiller and Refrigerator with a 0-star compartment
4	Refrigerator with a one-star compartment

5	Refrigerator with a two-star compartment
6	Refrigerator with a three-star compartment
7	Refrigerator-freezer
8	Upright freezer
9	Chest freezer
10	Multi-use and other refrigerating appliances

Source: Adapted from (European Regulation, 2010)

The definition of the "frozen-food storage compartment" mentioned in the Regulation, describes "one-star compartment" as a frozen-food compartment in which the temperature it not warmer than -6ºC (minus six degrees Celsius), "two-star compartment" as a frozen-food compartment in which the temperature it not warmer than -12ºC (minus twelve degrees Celsius), "three-star compartment" as a frozen-food compartment in which the temperature it not warmer than -18ºC (minus eighteen degrees Celsius).

Additionally, two extra definitions, "0-star compartment" as a frozen-food compartment in which the temperature it not warmer than 0ºC (zero degrees Celsius) and "four-star compartment" as a frozen-food suitable for freezing at least 4,5kg of food per 100L (one hundred liters) of storage volume, on a period of 24 hours, from ambient temperature down to -18ºC (minus eighteen degrees Celsius).

4.1.2.2 German Calculation Methodology

The calculation in the European program also demands elementary calculation after having access to the input's value. Using the input values from Table 6 and the formulas described below. The results will be exposed and discussed in the next section.

The classification follows 3 (three) formulas to calculate the Energy Efficiency Index for Germany. For instance, Equivalent Volume (Equation 4), Standard Annual Energy Consumption (Equation 5) and Energy Efficiency Index (Equation 6).

$$V_{eq} = \left[\sum_{c=1}^{c=n} V_c \times \frac{(25 - T_c)}{20} \times FF_c\right] \times CC \times BI \quad (4)$$

$$SAE_c = V_{eq} \times M + N + CH \quad (5)$$

$$EEI = \frac{AE_c}{SAE_c} \times 100 \quad (6)$$

where:

$V_{eq} = Equivalent\ Volume\ of\ a\ household\ refrigerating\ appliance$

$n = Number\ of\ compartments$

$V_c = Volume\ of\ the\ analyzed\ compartment$

$T_c = The\ temperature\ of\ the\ analyzed\ compartment$

$FF_c = Frost - free\ of\ the\ analyzed\ compartment$

$CC = Climate\ class\ as\ set\ out\ in\ Table$

$BI = Built\ In\ as\ set\ out\ in\ table$

$SAE_c = Standard\ Annual\ Energy\ Consumption$

$M\ and\ N\ are\ correction\ factors\ for\ each\ model\ class$

$CH\ is\ equal\ to\ 50\ {}^{kWh}/_{year}{}^{*}$

$AE_c = Annual\ Energy\ Consumption$

*This value was defined in the Regulation for appliances with a chill compartment with a storage of at least 15 liters

4.1.3 United States

The program in the United States is supervised by the Department of Energy and by the Federal Trade Commission. The program is a consequence of the Law in respect to the Energy Policy and Conservation Act – EPCA.

EPCA prescribes specific criteria for DOE to consider when amending standards for covered products. As indicated above, any amended standard for a covered product must be designed to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. The criterion prescribed by the EPCA says that any amended standard to be accepted shall be economically justified by DOE, following the idea of 7 (seven) factors where its benefits need to exceed its burdens.

The seven principles as described in the Department of Energy (DOE, 2011):

1. The economic impact of the standard on manufactures and consumers of the products subject to the standard;
2. The savings in operating costs throughout the estimated average life of the covered products in the type (or class) compared to any increase in the price, initial charges, or maintenance expenses for the covered products that are likely result from the imposition of the standard;
3. The total projected amount of energy savings likely to result directly from the imposition of the standard;
4. Any lessening of the utility or the performance of the covered products likely to result from the imposition of the standard;
5. The impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the imposition of the standard;
6. The need for national energy conservation;
7. Other factors the Secretary of Energy (Secretary) considers relevant.

The EPCA also offers a restrictive condition, named "anti-backsliding", provision prevents DOE from stipulating any amended standard that either increase the maximum allowed energy use or decreases the minimum required energy efficiency of a covered product.

4.1.3.1 United States Product Classification Classes

In order to increase the precision of the standards set, generally DOE divides covered products into classes by the type of energy usage, or by capacity or other performance-related feature that justifies a different standard for the aimed products.

The most recent classification is defined on Table 4, described in the CFR document.

Table 4 – American Refrigerator Classes

Class	Designation
1	Refrigerators and refrigerator-freezers with manual defrost.
2	Refrigerator-freezers—partial automatic defrost.
3	Refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker.
4	Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker.

5	Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker.
6	Refrigerator-freezers—automatic defrost with top-mounted freezer with through-the-door ice service.
7	Refrigerator-freezers—automatic defrost with side-mounted freezer with through-the-door ice service.
8	Upright freezers with manual defrost.
9	Upright freezers with automatic defrost without an automatic icemaker.
10	Chest freezers with manual defrost and all other freezers except compact freezers.
11	Compact refrigerators and refrigerator-freezers with manual defrost.
12	Compact refrigerator-freezers—partial automatic defrost.
13	Compact refrigerator-freezers—automatic defrost with top-mounted freezer.
14	Compact refrigerator-freezers—automatic defrost with side-mounted freezer.
15	Compact refrigerator-freezers—automatic defrost with bottom-mounted freezer.
16	Compact upright freezers with manual defrost.
17	Compact upright freezers with automatic defrost.
18	Compact chest freezers.

Source: Adapted from U.S. Department of Energy (2012)

4.1.4 Countries comparison

In this sub-section, the comparable information and data from the three programs are presented in Table 5. More specifically, the access characteristic, information about its starting date, number of classes, volume range, classification scale and additional technical variables covered in the equations.

Table 5 – Energy Labelling Program Comparison

Program	Brazil	Europe	United States
Access Characteristic	Voluntary	Voluntary	Compulsory
Started on	1985	1992	1992
Number of Classes	7	10	18
Volume range	n.s.*	10-1500	n.s.*

Scale	A to E	A+++ to G	Savings' range bar
Climate Class factor	No	Yes	No
Built In factor	no	Yes	no
Frost-free factor	Yes	Yes	Yes

Source: The Author (2018).

*n.s. – not specified

The starting date mentioned in Table 5 refers to the date when Household Refrigerators and Freezer started been labelled.

The compulsory strategy inforce in the United States facilitates the data compilation from an extensive list of appliances if put aside with the Brazilian and European's labelling program.

The "volume range", attributed to restricting the household refrigerators and freezer's size, was only mentioned in the European labelling programs. However, the EnergyStar® program in the United States, representing an Energy Efficiency Award Program, the "volume range" to receive the label is mentioned.

After reviewed the information presented from each source, for instance norms, directives, specific regulation, ministerial order or ordinance, it was noticed that all the amends on the labelling programs were also accompanied by alterations on the formatting of the documents that are available to study. Some alterations are related to text formatting in paragraphs or columns in some cases, but also noticed changes in the regulation's information inside the regulation's sub-sections. Moreover, it was observed modification in the section order, association and disjoint of content. The aspect makes it difficult to understand the transition of one regulation to the next one that came to be its substitute.

4.2 Energy Efficiency Label Program Comparison

4.2.1 Defining the inputs

In this sub-section, 3 models of refrigerator were chosen. The first approach was to select 2 refrigerator-freezer from the same supplier, with the same internal volume to compare. More specifically, one sold in Brazil while the other in Europe.

The supplier that fulfilled the first criterion is Electrolux®. The information from the models selected in Brazil was obtained from the latest INMETRO's RPA. The information

from the model selected in Europe was obtained in the supplier's website, the models selected are detailed on the Table 6.

The second approach was to analyze the classification of one refrigerator-freezer labeled "A" in Brazil, that is the highest class it can get certified, evaluating how it would be labeled in the European program, the data of the selected model is also detailed on Table 6.

Table 6 – Selected Refrigerator-freezer Information

Country		Brazil	Europe	Brazil
Supplier		Electrolux®	Electrolux®	Electrolux®
Model		DC33A	ENN2853COW	DC34A
Refrigerator Volume [L]		201	192	207
Freezer Volume [L]		50	61	53
Energy Consumption [kWh]	Month	40.9	-	38.4
	Annual	-	291	-
Energy Efficiency Index	For Brazil	0.930	-	0.853
	For Europe	-	41	-
Classification	For Brazil	B	-	A
	For Europe	-	A+	-

Source: The Author (2018).

4.2.2 Label Classification Comparison

In this sub-section, as mentioned in the Methodology section, two of the programs were tested, by using the equations mentioned earlier, in order to compare the label classification. In the first approach two procedures took place.

Firstly, the label classification was tested by inputting the information from the two selected models in its particular program, furthermore, allowing the label to be checked with the information displayed by retailer.

Secondly, each of the products from the first approach was submitted for testing on the other country's labelling program. Giving an idea of what could happen, concerning the labelling classification, by the exchange of products overseas.

Both parts of the first approach were calculated using the equations mentioned in the previous section. In addition, giving a better guidance with visual graphics, this sub-section contains a simulated label template of each procedure. Where the label template was adapted by the Author to mimic a real label in this methodology.

4.2.2.1 Energy Labelling Program Checking

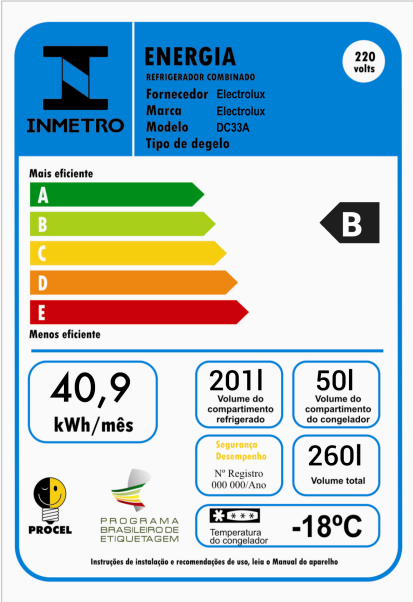

Figure 1: Simulated Brazilian Label. Source: Adapted (Jornada, 2015; The Author, 2018)

As observed, Figure 1, the information available by the supplier on the product's datasheet was tested on the presented Brazilian equations, resulting on the simulated label, where it mimics the ENCE label.

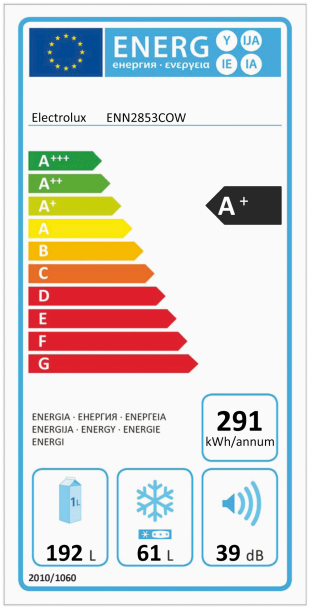

Figure 2: Simulated European Label. Source: Adapted (European Parliament, 2010; The Author, 2018)

Continuing, Figure 2, the information available by the supplier on the product's

datasheet was tested on the presented European equations, resulting on the simulated label, where it mimics the real label.

The information displayed on the sources, from both programs, matches with the classification that the regulatory body attributed.

4.2.2.2 Energy Labelling Exchange

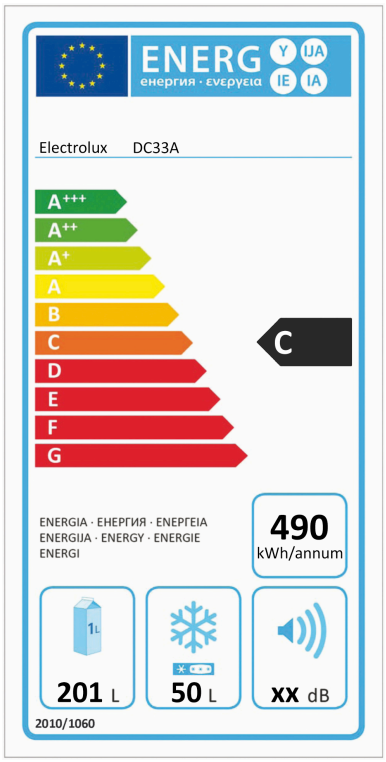

Figure 3: Exchanged Brazilian Model's Label. Source: Adapted (European Parliament, 2010; The Author, 2018)

For Figure 3, the selected Brazilian model was tested with the European equations and simulated its design and classification as it was sold in Germany. The information of decibels was not filled because the Brazilian model datasheet available from the supplier did not mention the airborne acoustical noise information.

It was noticed the decrease of classification class for the selected model. Achieving the sixth position out of ten classes.

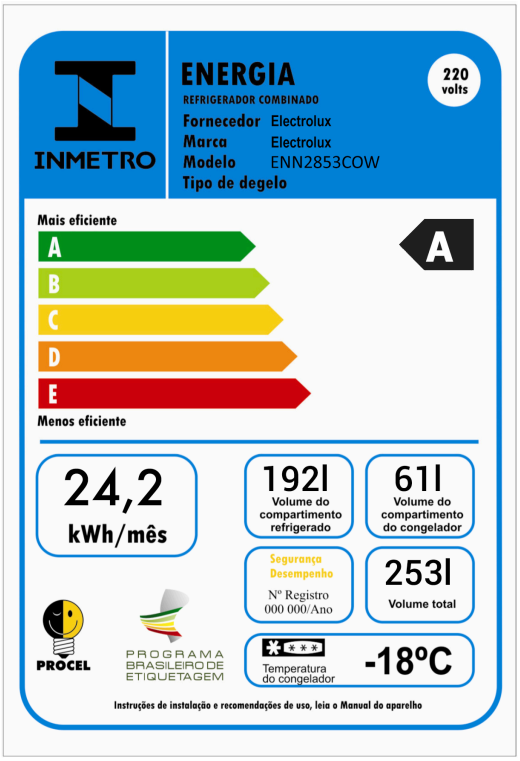

Figure 4: Exchanged European Model's Label. Source: Adapted (Jornada, 2015; The Author, 2018)

Repeating the calculation from the first approach, but in this time switching the European model, testing it on the Brazilian equations.

The European model, that in Germany is sold as an "A+" model, the third position in efficiency index, did fit on the highest classification in Brazil, labelled as "A" model.

4.2.2.3 Energy Labelling Benchmark

In addition, a third model, already describe in the Methodology section, was tested on the European program. This procedure took part to compare the behavior of one model, placed on the highest labelling class in Brazil, on the labelling program applied in Germany.

However, in this section, when checking the information declared by the supplier with the value obtained at INMETRO's RPA, after applying the equation available in (Jornada, 2015) the value obtained from the equations led us to believe that the product was misplaced. The value available in the latest proceeds with the value obtained through the equations, the misplacement is related with the Table used, available in Appendix A.

Nevertheless, for the objective of this sub-section, that was to compare a Brazilian class "A" refrigerator through labelling regulation in force Germany was satisfactory, and for disappointment, yet, the lower class of the Brazilian model if compared to European standards.

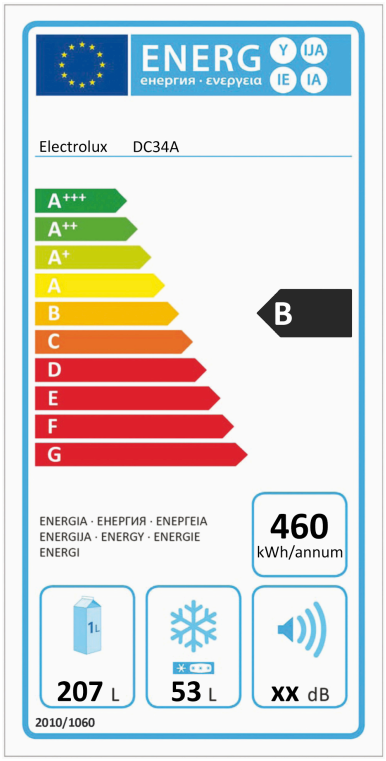

Figure 3: Class "A" Model by EU Regulation. Source: Adapted (European Parliament, 2010; The Author, 2018)

The selected model, placed "B", the fifth position on efficiency in Europe. There is a big gap between the "A" class in Brazil if compared to a "B" class in Europe.

4.3 Discussion of Results

Most significantly, as mentioned on Table 5, climate correlation is considered in the European labelling program, multiplying the Equivalent Volume equation by a factors that could vary from 1 to 1,2. This variation is capable of altering the classification on average 5 points to a higher efficiency position. Considering that the scale in Europe changes every 11 (eleven) points on the scale, the affirmation that the climate correlation plays a relevant factor is true. In contrast to the Brazilian labelling program, it is mentioned that all the correlations were assumed with a tropical (T) climate correlation factor. This leads to misinformation as the energy consumption value displayed on the label could vary significantly if the product was in used in Fortaleza, a city on extreme north of Brazil, or in Porto Alegre, a city south from the Capricorn Tropic.

5 CONCLUSION

By carrying out this study, it was possible to understand the importance of energy efficiency and how it can impact on a global scale, helping to reduce the CO2 emissions. Nevertheless, it was noticed a lack of regulation, with respect on delivering the documental information by each program's interface. Either there are complex websites or perhaps no website, it was observed in the case of the EnergyGuide Program. The same problem was observed in INMETRO's website. There were no updated regulations. This can lead to misinformation or distrusted information.

Another important factor referenced in the Introduction section was the connection between the Global Economic situation on the 70's energy crises and the turning point for the labelling programs. This can lead us to hope for another big change in a near future, considering the diffusion of the renewable mindset and renewable energy generation, powered by solar, wind and biofuels.

In summary, considering the objectives of this project which were to identify, to compare and to analyze programs associated to the energy efficiency labelling for household refrigeration appliances, considering the examples of Brazil, Germany and the United States, the results were satisfactory.

The identified programs are ENCE, promoted by PBR/INMETRO in Brazil, Energy Label organized by the European Parliament together with the Council (EU) and EnergyGuide organized by FTC in cooperation with DOE.

It was observed a proximity concerning the calculation methodologies for ENCE and Energy Label (EU).

Besides the framework of the label in 2003 was almost identical to the European design. Nevertheless, currently the Brazilian framework is updated to a more sophisticated design, but both are still on the same style of formats and colors.

It was also mentioned the difference on the appliances' classification with letters A to G to the "Savings' range price", when comparing both ENCE and Energy Label (EU) to Energyguide.

A deeper study carried out in situ, testing and discussing with the responsible for the regulatory bodies and for setting the standards could have brought more detailed information. Other investigation proposal could include different products for testing and comparison as well to discuss standard behaviors that could improve the results of the programs.

This study was crucial for the author to attain knowledge about the thematic, building skills that are fundamental when working as an Energy Engineer.

REFERENCES

ALLIANCE TO SAVE ENERGY (Org.). **The History of Energy Efficiency**. 2013. Available from: https://www.ase.org/sites/ase.org/files/resources/Media%20browser/ee_commission_history_report_2-1-13.pdf. Access in: 12 Sep. 2018.

CARDOSO, Rafael Balbino. ***Avaliação da economia de Energia Atribuída ao Programa Selo PROCEL em freezers e Refrigeradores***. 2008. 189 f. Universidade Federal de Itajubá, 2008. Available from: http://saturno.unifei.edu.br/bim/0032109.pdf. Access in: 14 Aug. 2018.

CLASP (Org.). **Standards & Labeling**. 2018. Available from: https://clasp.ngo/impact/standards-labeling. Access in: 17 Aug. 2018.

DAVIS, Lucas W.; METCALF, Gilbert E.. **Does Better Information Lead to Better Choices? Evidence from Energy-Efficiency Labels**. 2015. Journal of The Association of Environmental and Resource Economists. California, set. 2016. p. 888-999. Access in: 17 Oct. 2018.

DE DEUS, NS; FELIZOLA, M.; DE, S.-C. ***O consumidor socioambiental e seu comportamento frente aos selos de produtos responsáveis***. 2010. Revista Brasileira de Administração Científica, 2010. Available from: http://sustenere.co/journals/index.php/rbadm/article/view/119. Access in: 27 Aug. 2018.

DENA (Org.). **No energy transition without energy efficiency**. 2018. Available from: https://www.dena.de/en/topics-projects/energy-efficiency/. Access in: 09 Aug. 2018.

DOE, U.S. DEPARTMENT OF ENERGY. **Rules and Regulations nº 10 CFR Part 430**. Energy Conservation Program: Energy Conservation Standards for Residential Refrigerators, Refrigerator- Freezers, and Freezers. Washington, DC, 15 Sept. 2011. v. 76, n.

179, p. 57516-57612. Available from: https://www.govinfo.gov/app/details/CFR-2018-title10-vol3/CFR-2018-title10-vol3-chapII-subchapD. Access in: 15 Oct. 2018.

DOE, U.S. DEPARTMENT OF ENERGY. **Rules and Regulations nº 16 CFR Part 305**. Commercial Practices: Energy and Water Use Labeling for Consumer Products Under the Energy Policy and Conservation Act ("ENERGY LABELING RULE"). Washington, DC, 29 Aug. 2007. Available from: https://www.govinfo.gov/app/details/CFR-2018-title16-vol1/CFR-2018-title16-vol1-part305. Access in: 16 Oct. 2018.

ENERGY STAR (Corp.). **Energy Star Products**: 20 YEARS OF HELPING AMERICA SAVE ENERGY SAVE MONEY AND PROTECT THE ENVIRONMENT. 2012. 50 slides, color. Available from: https://www.energystar.gov/index.cfm?c=about.20_years. Access in: 22 Sept. 2018.

EUROPEAN PARLIAMENT; COUNCIL (EU). **Directive 92/75/EEC**: Labelling and Standard Product Information of the Consumption of Energy and Other Resources by Household Appliances. 1992. Brussels, 1 Jan. 1994. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0075&qid=1544574828821&from=EN. Access in: 29 Aug. 2018.

EUROPEAN PARLIAMENT; COUNCIL (EU). **Directive 2010/30/EU**: Labelling and Standard Product Information of the Consumption of Energy and Other Resources by Energy-Related Products. 2010. Strasburg, 31 Jul. 2011. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0030&from=EN. Access in: 27 Aug. 2018.

EUROPEAN PARLIAMENT; COUNCIL (EU). **Regulation (EU) 1060/2010**: Energy Labelling of Household Refrigerating Appliances. 2010. Brussels, 30 Nov. 2011. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010R1060&from=EN. Access in: 27 Aug. 2018.

FEDERAL MINISTRY FOR ECONOMIC AFFAIRS AND ENERGY (BMWi); NAPE. **Making more out of energy National Action Plan on Energy Efficiency: A good bit**

of work. 2014. Munich, 2014. 46 p. Available from: https://www.bmwi.de/Redaktion/EN/Publikationen/nape-national-action-plan-on-energy-efficiency.pdf. Access in: 29 Sep. 2018.

GALARRAGA, I.; GONZÁLEZ-EGUINO, M.; HERES, D.. **Evaluating the role of energy efficiency labels in the prices of household appliances: the case of refrigerators**. 2011. 10 f. Basque Centre for Climate Change. Available from: http://www.bc3research.org/lits_publications.html. Access in: 30 Sep. 2018.

GUÉRON, A. L.. ***Rotulagem e certificação ambiental: uma base para subsidiar a análise da certificação florestal no Brasil***. 2003. 112 f. Tese (Mestrado) - Curso de Mestrado em Ciências em Planejamento Energético, Programa de Pós-graduação em Engenharia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2003. Available from: http://antigo.ppe.ufrj.br/ppe/production/tesis/algueron.pdf. Access in: 02 Nov. 2018.

HADDAD, Jamil. ***Possíveis avanços para a eficiência energética no Brasil e como a regulação pode contribuir para seu aprimoramento***. VI *Congresso brasileiro de regulação*. Rio de Janeiro, 2009. Available from: http://www.workoutenergy.com.br/abar/cbr/Trab1102.pdf. Access in: 15 Aug. 2018.

INMETRO (Org.). **REGULAMENTO ESPECÍFICO PARA USO DA ETIQUETA NACIONAL DE CONSERVAÇÃO DE ENERGIA – ENCE**: LINHA DE REFRIGERADORES E ASSEMELHADOS. 2003. Available from: http://www.inmetro.gov.br/consumidor/pdf/resp001.pdf. Access in: 14 Aug. 2018.

INMETRO (Org.). **About Inmetro**. 2018. Available from: http://www.inmetro.gov.br/english/institucional/index.asp. Access in: 08 Aug. 2018.

JOLLANDS, N.; PASQUIER, S.. **Implementing energy efficiency policies: are IEA member countries on track?**. 2009. Paris: OECD/International Energy Agency, 2009. 125 p. Available from: https://www.iea.org/publications/freepublications/publication/implementingee2009.pdf. Access in: 12 Sep. 2018.

JORNADA, JOÃO ALZIRO HERZ DA. **Portaria n.o 20, de 01 de fevereiro de 2006**. 2006. Available from: http://www.inmetro.gov.br/legislacao/rtac/pdf/RTAC001000.pdf. Access in: 18 Oct. 2018.

JORNADA, JOÃO ALZIRO HERZ DA. **Portaria n.o 577, de 18 de novembro de 2015**. 2015. Available from: http://www.inmetro.gov.br/legislacao/rtac/pdf/RTAC002335.pdf. Access in: 18 Nov. 2018.

KOHLRAUSCH, A. K.. **A Rotulagem Ambiental no Auxílio à Formação de Consumidores Conscientes**. 2003. 153f. Dissertação (Mestrado em Engenharia de Produção) – Programa de Pós-graduação em Engenharia de produção, UFSC, Florianópolis, 2003. Available from: https://repositorio.ufsc.br/bitstream/handle/123456789/85417/224372.pdf?sequence=1&isAllowed=y. Access in: 10 Sep. 2018.

MÁRCIO PEREIRA ZIMMERMANN (Brazil). Coordenação Geral (Org.). **Plano Nacional de Energia 2030**. Brasília: Eletrobrás - A Energia Que Movimenta O Brasil, 2007. 244 p. (CDU 621.3(81) "2030": 338.28).

NOGUEIRA, Luiz A. H.. **Uso racional: a fonte energética oculta. Estudos Avançados**. 2007. Available from: http://www.scielo.br/pdf/%0D/ea/v21n59/a07v2159.pdf. Access: 05 Aug. 2018.

PROGRAMA NACIONAL DE CONSERVAÇÃO DE ENERGIA ELÉTRICA. **Regulamento para Concessão do selo PROCEL de Economia de Energia**. 5 ed. Rio de Janeiro, 2013. 12 p.

SILVA, H. **Estudo das Principais Políticas para Melhoria da Eficiência Energética no Setor Elétrico**. 2014. Available from: https://repositorio.unesp.br/handle/11449/123008. Access in: 27 Aug. 2018.

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Finalizo com uma frase que sempre me conforta:

“ Seja a mudança que quer ver no mundo. ” Mahatma Gandhi

APPENDIX A – Brazilian Labelling Program Classification Scale

*Household refrigeration appliances using R141b as refrigerant fluid

Classes	Refrigerador	Combinado	Combinado frost-free	Congelador vertical	Congelador vertical frost-free	Congelador horizontal
A	0,820	0,820	0,812	0,820	0,820	0,820
B	0,893	0,893	0,884	0,893	0,893	0,893
C	0,972	0,972	0,963	0,972	0,972	0,972
D	1,059	1,059	1,049	1,059	1,059	1,059
E	> 1,059	> 1,059	> 1,049	> 1,059	> 1,059	> 1,059

Source: Adapted from (Jornada, 2006)

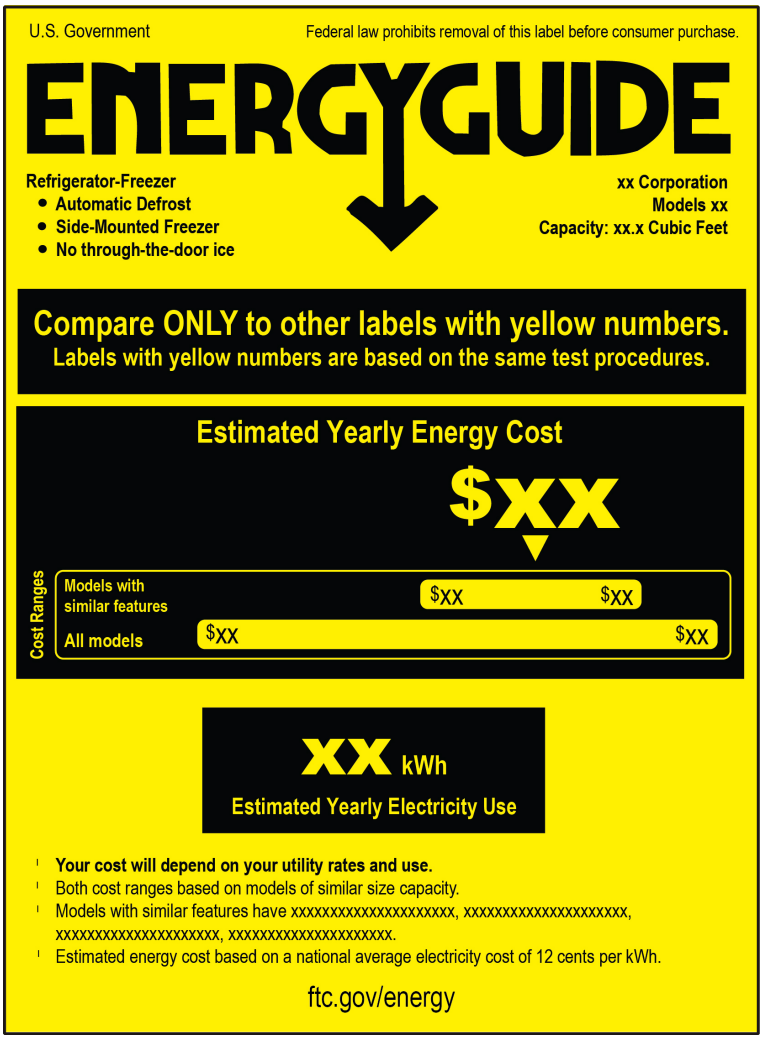
APPENDIX B – European Labelling Program Classification Scale

Energy efficiency classes from 1 July 2014

Energy efficiency class	Energy Efficiency Index
A+++ (most efficient)	$EEI < 22$
A++	$22 \leq EEI < 33$
A+	$33 \leq EEI < \mathbf{42}$
A	$\mathbf{42} \leq EEI < 55$
B	$55 \leq EEI < 75$
C	$75 \leq EEI < 95$
D	$95 \leq EEI < 110$
E	$110 \leq EEI < 125$
F	$125 \leq EEI < 150$
G (least efficient)	$EEI \geq 150$

Source: Adapted from (xxx, 2006)

APPENDIX C – EnergyGuide Refrigerator-Freezer Label



Source: (U.S. DEPARTMENT OF ENERGY, 2007)